Underreporting of habitual food intake is explained by undereating in highly motivated lean women.

Underreporting of Habitual Food Intake Is Explained by Undereating in Highly Motivated Lean Women

Annelies H. C. Goris[1] and Klaas R. Westerterp

Department of Human Biology, Maastricht University, The Netherlands

ABSTRACT Underreporting of habitual food intake can be explained by underrecording and/or undereating. This study was designed to discriminate between the two errors mentioned, by measuring energy and water balance. Twenty-four lean female dieticians were recruited as subjects. Energy intake and water intake were measured for 1 wk with a weighed dietary record. Energy expenditure was estimated from measurements of resting metabolic rate, and measured physical activity with a triaxial accelerometer for movement registration. Water loss was estimated with deuterium-labeled water. Energy balance was determined by measuring the change in body mass over a nonrecording week (preceding the recording week) and over the recording week. Mean energy and water intake were 8.5 ± 1.0 MJ/d and 2.3 ± 0.5 L/d. The change in body mass in the nonrecording week was 0.1 ± 0.6 kg and in the recording week −0.6 ± 0.8 kg (paired *t* test; $P = 0.02$), indicating 16% undereating. Recorded water intake plus calculated metabolic water closely matched measured water loss ($r = 0.93$; $P = 0.0001$), which indicated a high recording precision. In conclusion, in the studied group of highly motivated lean women, there was 16% underreporting of habitual food intake, which could be explained by undereating. J. Nutr. 129: 878–882, 1999.

KEY WORDS: • *energy-intake* • *water-intake* • *energy-balance* • *water-balance* • *women*

Nutrition research requires a valid measurement of habitual food intake. Standard methods used for determining habitual food intake include interviewing subjects about their usual or past intake and food records kept by the subjects at the time of consumption. Yet, measurements of food intake have often been prone to errors, e.g., underrecording or undereating. Since the doubly labeled water method has come into use for the validation of energy intake (assuming energy balance), many studies have found a self-reported energy intake below measured energy expenditure (Bandini et al. 1990 and 1997, Buhl et al. 1995, Davies and Coward 1994, Edwards et al. 1993, Kempen et al. 1995, Lichtman et al. 1992, Livingstone et al. 1990 and 1992, Martin et al. 1996, Pannemans et al. 1996, Prentice et al. 1986, Schoeller 1990a and 1990b , Schulz et al. 1989, Sjödin et al. 1994, Velthuis-te Wierik et al. 1995, Westerterp et al. 1991). The doubly labeled water method is an accurate and precise method to measure energy expenditure in free-living subjects.

Underreporting of habitual food intake (i.e., a discrepancy between energy intake and expenditure) can be divided into underrecording and undereating, but the distinction has seldom been made. By underrecording is meant a discrepancy between energy intake and measured energy expenditure with no change in body mass, and by undereating a discrepancy accompanied by a decline in body mass over the food-recording interval (Milne et al. 1991). Milne et al. (1991) tried to distinguish underrecording and undereating in their study. Energy expenditure was assessed from predicted basal metabolic rate (calculated from subjects height, weight and age) and the physical activity level (obtained by activity diaries for each day). Body mass was measured at the start and end of the recording week at the same time of day, but not necessarily in subjects with an empty stomach. The size of underreporting, and thus of undereating and underrecording, could only be estimated in this study.

Studies that measured energy intake with a food record and energy expenditure with the doubly labeled water method found discrepancies ranging from 20 to 50% in obese subjects (Bandini et al. 1990, Buhl et al. 1995, Kempen et al. 1995, Lichtman et al. 1992, Prentice et al. 1986, Schoeller 1990a and 1990b, Velthuis-te Wierik et al. 1995, Westerterp et al. 1991) and from 0 to 30% in lean subjects (Bandini et al. 1990 and 1997, Davies and Coward 1994, Edwards et al. 1993, Livingstone et al. 1990 and 1992, Martin et al. 1996, Pannemans et al. 1993, Schoeller 1990a and 1990b, Schulz et al. 1989, Sjödin et al. 1994, Westerterp et al. 1991). One of the few studies that found a reported energy intake equal to measured energy expenditure was a study of Sjödin et al. (1994). This study was done with eight cross country skiers (four men and four women) who reported their food intake for four consecutive days assisted by two dietitians who were present at all meals, likely an ideal situation. Other studies by Davies and Coward (1994) in children from 1.5 to 4.5 y, by Westerterp et al. (1991) in adults before an exercise training and by Schulz et al. (1989) in students found a reported energy intake nearly equal to energy expenditure. Most other studies found discrepancies >5% between energy intake and expenditure;these were attributed to underreporting. Measurements

[1] To whom correspondence should be addressed.

Manuscript received 5 March 1998. Initial review completed 15 June 1998. Revision accepted 14 December.

of body mass were done in some of the above-mentioned studies, but a determination of the fraction of underreporting attributed to undereating could not be made (Bandini et al. 1990, Buhl et al. 1995, Davies and Coward 1994, Edwards et al. 1993, Kempen et al. 1995, Lichtman et al. 1992, Martin et al. 1996, Pannemans et al. 1996, Prentice et al. 1986, Schoeller 1990a, and 1990b, Schulz et al. 1989, Sjödin et al. 1994, Velthuis-te Wierik et al. 1995, Westerterp et al. 1991). Other studies did not measure body mass at the start and end of the recording interval and attributed the underreporting completely to underrecording of energy intake (Bandini et al. 1997, Livingstone et al. 1990 and 1992). Repeated measurements of body mass on an accurate scale in the morning before any beverage or food consumption and after voiding are necessary to detect undereating. This might be a reason for not addressing the issue of undereating in most studies.

In addition, a distinction between underrecording and undereating is difficult to make because a decline in body mass does not necessarily have to exclude underrecording; both can occur at the same time. An independent measure for underrecording is therefore necessary.

This study was designed to discriminate between underrecording and undereating by comparing reported food intake with measured energy expenditure and water loss. Food and water intake were measured with a 7-d weighed food record, and energy expenditure was estimated by measurements of resting metabolic rate and physical activity. A triaxial accelerometer for movement registration measured physical activity [validated by Bouten et al. (1996) with doubly labeled water], a less expensive alternative for the doubly labeled water method. Water loss was measured with deuterium elimination. Under normal conditions, water balance is preserved, and water intake matches water loss. Water loss might slightly deviate from water intake during the postovulatory phase of the menstrual cycle for premenopausal women, but this is very small (e.g., a water retention of 0.5 L/wk gives, on a total water loss of 21 L/wk, a 2% deviation of measured water loss)."Underdrinking" because of food recording is not realistic. Thus a water intake, corrected for metabolic water, lower than water loss indicates underrecording. Portion size errors have to be minimal to be able to distinguish underrecording from undereating. Therefore, dietitians were chosen as subjects because they are familiar with accurately weighing and reporting food intake. The objective of this study was to sort out the two errors that contribute to underreporting of habitual food intake, i.e., underrecording and undereating.

MATERIALS AND METHODS

Design. Food intake was measured with a 7-d food record. Energy balance was monitored by measurement of body mass. Subjects were weighed 1 wk before the start of the food-recording week, at the start and at the end of the recording week. Thus, possible weight fluctuations because of food recording could be compared with normal weight fluctuations. During wk 1, the nonrecording week, there were no further measurements. In wk 2, energy and water intake were measured with a weighed food record. Energy expenditure was estimated by two measurements of resting energy expenditure (at the start and end of the recording week) and by the assessment of physical activity during the whole recording week. Water loss was measured with deuterium elimination.

Subjects. Twenty-seven dietitians were recruited from the Maastricht University, university hospital, home nursing association and dietitian practices in Maastricht and the surrounding area. Subjects were informed about the goal of the study to stimulate them to record their food intake accurately. All subjects were healthy women with a mean age of 34 ± 9 y (range 22–60 y) and a mean body mass index of 22.1 ± 2.3 kg/m^2 (range 17.4–26.0). Two subjects were postmenopausal. Subjects who were pregnant, lactating or dieting were not included in the study. The protocol was approved by the university ethics committee.

Body mass. Body mass was measured three times at 7-d intervals. Because weight fluctuations can be influenced by phase of the menstrual cycle, the phase of the cycle in the recording week was noted. Subjects were weighed (in underwear) in the morning before any beverage or food consumption and after voiding, on a digital balance accurate to 0.01 kg (Sauter, type E1200, Albstadt 1, Ebingen, Germany).

Food and water intake. A 7-d weighed food record was chosen because it does not rely on the memory of a subject and it is commonly used for measuring recent habitual food intake of individuals and groups. Subjects were instructed to weigh everything they ate and drank on an electronic scale (EKS; Sélestat, Sweden; max. 2000 g; accurate to 1 g) and record it in a structured food diary. The food records were converted into intakes of total energy and water with a computer program based on food tables (Becel Nutrition Program 1988).

The amount of metabolic water was estimated from protein, fat and carbohydrate intake derived from the 7-d food record and from the change in body mass. Oxidation water is 0.41 mL/g for protein, 1.07 mL/g for fat and 0.6 mL/g for carbohydrate (Fjeld et al. 1988). A change in body mass of 1 kg is assumed to be a change of 0.75 kg fat mass and 0.25 kg fat-free mass. Fat mass is pure fat and fat-free mass is 73% water and 27% protein (Westerterp et al. 1995).

Energy expenditure. Energy expenditure (EE)[2] was estimated from measured resting metabolic rate (RMR)and physical activity (PA). Diet-induced (EE) was not measured in this study; it is a constant fraction of 10% of total energy expenditure in subjects consuming an average mixed diet (Weststrate et al. 1989).

Resting metabolic rate was measured by means of an open circuit ventilated hood system, in the morning in a fasting state while subjects were lying for 30 min in supine position. Gas analyses were performed by a paramagnetic oxygen analyzer (Servomex type 500A, Crowborough Sussex, UK) and an infrared carbon dioxide analyzer (Servomex type 500A), similar to the analysis system described by Schoffelen et al. (1997). Weir's formulas (1949) were used for calculating RMR.

Physical activity was registered with a triaxial accelerometer for movement registration (Tracmor, Philips Research, Eindhoven, The Netherlands). The Tracmor was an improved version (same principle, but smaller 7 × 2 × 0.8 cm) of the Tracmor used in previous studies (Bouten et al. 1996). In short, the Tracmor measures accelerations in the anteroposterior, mediolateral and vertical directions. The Tracmor has been validated against doubly labeled water (Bouten et al. 1996). Subjects wore the Tracmor in a belt at the back of the waist during waking hours and recorded the times at which they got up, put on and off the Tracmor and when they went to bed. The registered accelerations in counts/minute were used as an objective measure for the physical activity level of each subject.

Water loss. Water loss over the recording week was measured with the deuterium elimination method (Fjeld et al. 1988). Subjects drank a deuterium (^2H_2O) dilution (70 g water with an enrichment of 5 atom % excess ^2H) after voiding (baseline urine sample) the evening before the start of the recording week. Elimination was calculated from two urine samples directly after dosing (at d 1 in the morning and evening) and two samples at the end of the observation period (d 7 in the evening, d 8 in the morning). Deuterium content was measured in urine samples with an isotope ratio mass spectrometer (Westerterp et al. 1996). Water loss was calculated from ^2H elimination with the equation of Fjeld et al. (1988), as described previously (Westerterp et al. 1992).

Questionnaire. At the end of the recording week, subjects filled in a questionnaire about their experiences with food recording to determine if they always weighed and recorded their food intake and if they changed their habitual food intake.

[2] Abbreviations used: EE, energy expenditure; EI, energy intake; PA, physical activity; RMR, resting metabolic rate.

TABLE 1

Reported intakes of energy and water and estimates of energy expenditure, body mass changes and water loss in lean healthy women[1]

Energy intake, *MJ/d*	8.5 ± 1.0 (6.1–10.4)
Resting metabolic rate, *MJ/d*	6.1 ± 0.5 (5.3–6.9)
Physical activity, *counts/min*	163 ± 70 (75–315)
Body mass change over the nonrecording week, *kg*	0.07 ± 0.59 (−0.96–1.36)
Body mass change over the recording week, *kg*	−0.57 ± 0.77* (−2.53–0.93)
Reported water intake, *L/d*	2.3 ± 0.5** (1.4–3.0)
Reported water intake + metabolic water,[2] *L/d*	2.6 ± 0.5** (1.7–3.3)
Water loss, *L/d*	3.0 ± 0.5 (2.0–3.9)

[1] Values are means ± SD (ranges), $n = 24$. Means are based on 7-d food diaries of 24 subjects and the ranges refer to differences among subjects.

[2] Metabolic water was calculated from reported protein, fat and carbohydrate intakes derived from the 7-d food record and from the change in body mass (1 kg change is 0.75 kg fat mass and 0.25 kg fat-free mass).

* Body mass change over the recording week was significantly different from body mass change over the nonrecording week (*t* test; $P < 0.02$).

** Water intake was significantly different from water loss (*t* test; $P < 0.01$).

Statistics. Twenty-seven subjects were recruited; three subjects were excluded from statistical analysis because of missing physical activity registration by the Tracmor.

Mean values and SD were calculated. A one-factor ANOVA for repeated measures and a Scheffé test (post-hoc) were used to compare the three measurements of body mass. The changes in body mass were compared with a paired *t* test. A factorial ANOVA test was used to measure the influence of the phase of the menstrual cycle on the body mass changes.

Measurements of RMR at the start and end of the recording week were compared with a paired *t* test and means were calculated if the two measurements did not differ significantly.

RMR, PA and body mass changes are all independent measures for energy metabolism. Multiple and simple regression analyses were used to assess the contribution of these independent variables to reported energy intake.

The ratio between energy intake and resting metabolic rate (EI/RMR) is often used to identify underreporting. For subjects in energy balance, EI/RMR ranges between a minimum of 1.1, in somebody with zero activity, and a higher value of ~2.5 in very active subjects. A low EI/RMR can be caused by underrecording or undereating. With simple regression analysis, the contribution of physical activity and the change in body mass to EI/RMR were tested. Significance was reached when $P < 0.05$. The StatView SE+ (1988, Abacus Concepts, Berkeley, CA) was used for statistical analysis.

RESULTS

The results of the three body mass measurements (mean ± SD) were, in sequence of time, 61.5 ± 8.1, 61.5 ± 8.0 and 61.0 ± 7.9 kg. The last mean body mass differed significantly from the first two measurements ($P < 0.01$). Mean body mass changes over the nonrecording and recording week (**Table 1**) differed significantly ($P < 0.02$) and were independent of the phase of the menstrual cycle ($P > 0.05$). **Figure 1** presents the individual changes in body mass over the nonrecording week and the recording week. The change in body mass indicated that most subjects (18 out of the 24) were in negative energy balance. The mean body mass loss of 0.57 kg over the recording week represented 17.1 MJ [1 kg body mass was assumed to be equivalent to 30 MJ (Westerterp et al. 1995)] or 2.4 MJ/d. Energy expenditure calculated from energy intake and body mass loss was 10.8 ± 2.8 MJ/d. The discrepancy between reported energy intake and calculated EE was 16 ± 29% of calculated EE.

The results of reported EI and estimated EE are summarized in Table 1. Measurements of RMR did not differ significantly from each other and mean values of both measurements were calculated for each subject. The mean ratio of energy intake to resting metabolic rate (EI/RMR) was 1.4 ± 0.2 for this group and ranged from 1.1 to 1.7.

Reported water intake plus calculated metabolic water correlated closely with measured water loss (water intake $= -0.29 + 0.99 \cdot$ water loss; $r = 0.92$, $P < 0.0001$), indicating a high recording precision. However, there was a significant difference of 0.3 L/d between total water loss and reported water intake plus the calculated amount of metabolic water (see Discussion).

Resting metabolic rate, physical activity and the change in body mass were all independently related to energy intake (**Table 2**) Together they explained 66% of the variation in energy intake.

The frequently adopted indicator for underreporting, EI/RMR, was positively related to body mass change ($r = 0.60$; $P < 0.01$) (**Fig. 2**). In a multiple regression analysis, PA explained an additional 17% of the variation.

The answers to the questionnaire subjects completed at the end of the recording week indicated that weighing and recording food intake for 7 d was quite a burden. However, according to their answers, subjects did not change their food pattern during the recording week.

DISCUSSION

In this study we found a discrepancy of 16% between reported EI and estimated energy expenditure. The level of

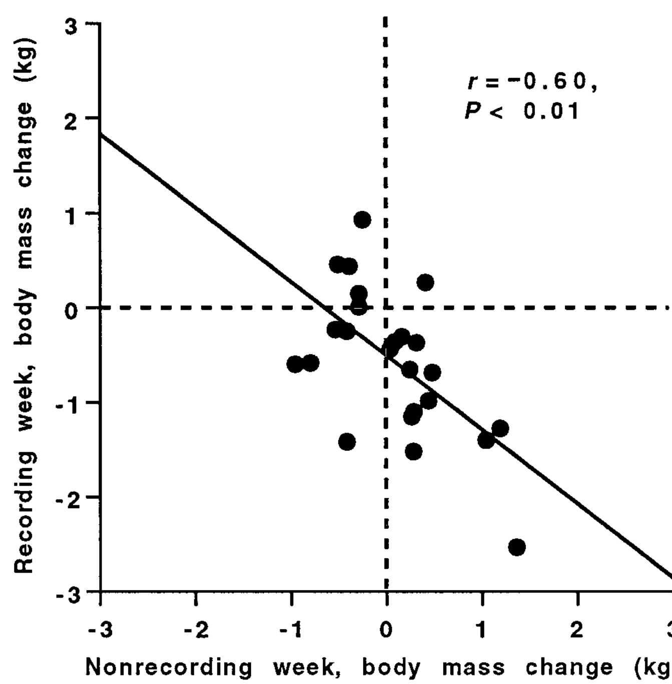

FIGURE 1 Individual body mass changes in lean healthy women ($n = 24$) over the nonrecording week, a week with no interventions, and over the recording week, a week in which subjects weighed and recorded their food intake.

TABLE 2

The attribution of resting metabolic rate, physical activity and body mass change over the recording week to energy intake in 24 lean healthy women and a simple and multiple regression analysis on energy intake

Energy intake	Explained variation	$P <$
	%	
Resting metabolic rate (RMR)	27	0.02
Physical activity (PA)	27	0.02
Δ body mass over recording week	25	0.01
RMR + PA + Δ body mass[1]	65	0.001

[1] The following equation, which predicts energy intake, can be derived from the multiple regression analysis: energy intake (kJ/d) = 2815 + 0.84 · RMR (kJ/d) + 5.3 · PA (counts/min) + 669 · Δ body mass (kg/wk).

underreporting of 16% falls in the range observed in other studies with lean subjects (Bandini et al. 1990, Bandini et al. 1997, Davies and Coward 1994, Edwards et al. 1993, Livingstone et al. 1990 and 1992, Martin et al. 1996, Pannemans et al. 1996, Schoeller 1990a and 1990b, Schulz et al. 1989, Sjödin et al. 1994, Westerterp et al. 1991). Here, underreporting could be attributed to undereating, because body mass declined significantly over the recording week.

The recording of food intake in this study was done accurately according to the measured water balance. The small shortage in water intake compared with water loss was also seen in other studies that measured the water balance (Westerterp et al. 1992 and 1996). The shortage in this study might be due to underestimation of the amount of calculated metabolic water or might be in the assumptions made on respiratory and cutaneous water loss and fractionation in the calculation of water loss. The amount of metabolic water was calculated from the carbohydrate, fat and protein intakes derived from the 7-d food record and from the change in body mass. To calculate the amount of metabolic water derived from the change in body mass, the mass ratio 75:25 for fat mass and fat-free mass was used. This ratio of mobilization or storage of energy between fat mass and fat-free mass is not a constant and might introduce an error into the calculation of metabolic water (Westerterp et al. 1995). A good recording of water intake does not necessarily imply that the same holds for the recording of food intake. However, most foodstuffs contain a certain amount of water; therefore, it was concluded that the food recording was also done accurately.

Subjects changed their habitual food intake in the recording week; this was probably done unconsciously according to the answers on the questionnaire. To indicate undereating, body mass changes in the recording week were compared with body mass changes in the nonrecording week. Body mass might fluctuate from one week to another; thus, normal body mass changes were excluded from changes caused by undereating. Milne et al. (1991) measured body mass changes only over the recording week. A significant weight loss (−0.28 kg/wk) from zero over the recording week was found. However, body mass was not measured in the morning after an overnight fast (with an empty stomach), which might give some error in the measured body mass changes over the recording week. The body mass changes were not related to energy intake, only in subgroups of large eaters vs. small eaters. It was therefore not entirely clear whether the body mass changes indicated undereating or whether they were simply normal weight fluctuations or measurement errors. Figure 1 presents changes in body mass over the nonrecording week and the recording week. The regression line goes not through zero, probably because of the intervention (weighing and recording food intake) in wk 2 or because the time interval was too short to measure energy balance. Edholm et al. (1955) measured energy expenditure and food intake in individual men for 2 wk and showed that mean energy expenditure was close to intake on a weekly and fortnightly basis. Individual intakes were highly variable from day to day and were often not in daily, weekly or even fortnightly balance with energy expenditure. Basiotis et al. (1987) found that the minimum time interval in which to measure habitual intake at an individual level was 31 d and 3 d at a group level. Seven days is the minimum number of days to measure mean energy balance and is probably the maximum number of days in which to keep a weighed food record; accuracy will drop if the time is extended because of declining motivation on the part of the subjects.

The ratio EE/RMR is known as physical activity level; if there is no underreporting, EE/RMR is equal to EI/RMR. The EI/RMR ratio is therefore often used in studies to identify underreporting. Goldberg et al. (1991) made cut-off limits to recognize underreporting at the group level. A physical activity level <1.35 is not very likely unless someone has a very inactive lifestyle. Therefore ratios of EI/RMR <1.35 indicate underreporting. But, as can be seen in Figure 2, there were subjects in this study with a ratio below and above 1.35 who lost weight. The ratio EI/RMR cannot identify all underreporters, only the very unlikely reporters. Black et al. (1997) compared the ratio EI/RMR with EI/EE and also arrived at the conclusion that the ratio EI/RMR cannot identify all underreporters; specific information about a person's physical activity is needed. Specific information about such physical activity was available in this study through the use of the Tracmor;thus conclusions could be made on an individual level. The output

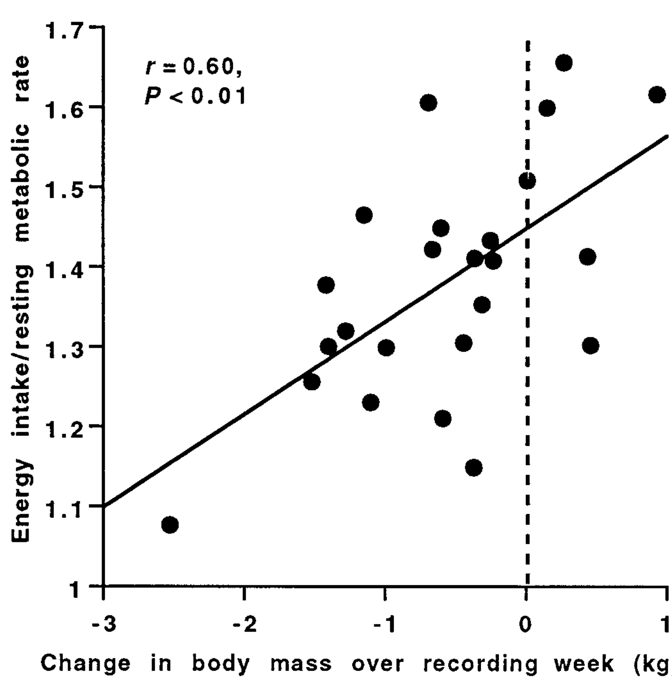

FIGURE 2 The contribution in lean healthy women (n = 24) of the change in body mass over the food-recording week to the energy intake/resting metabolic rate ratio, with the linear regression line; energy intake/resting metabolic rate = 1.4 + 0.1 · body mass change (kg/wk).

of the Tracmor explained 27% of the variation in energy intake.

This study was done with dietitians, a population that would be expected to report very accurately. The results of this study can therefore not be used for other populations, but the methods used certainly apply to other studies.

In summary, underreporting of habitual food intake does not necessarily mean that subjects are dishonest about their food intake. In this study, we found that the recording precision of subjects was high, but they changed their food pattern and therefore lost weight. The underreporting of ~16% could be explained by undereating in this group of motivated, lean women.

LITERATURE CITED

Bandini, L. G., Cyr, H., Must, A. & Dietz, W. H. (1997) Validity of reported energy intake in preadolescent girls. Am. J. Clin. Nutr. 65(suppl.): 1138s–1141s.

Bandini, L. G., Schoeller, D. A., Cyr, H. N. & Dietz, W. H. (1990) Validity of reported energy intake in obese and nonobese adolescents. Am. J. Clin. Nutr. 52: 421–425.

Basiotis, P. P., Welsh, S. O., Cronin, F. J., Kelsay. J. L. & Mertz, W. (1987) Number of days of food intake records required to estimate individual and group nutrient intakes with defined confidence. J. Nutr. 117: 1638–1641.

Becel, Nederlandse Voedingsstoffenbestand (NEVO). Dutch Nutrient Database 1989/1990. Zeist, The Netherlands: Stichting NEVO (in Dutch), 1989.

Black, A. E., Bingham, S. A., Johansson, G. & Coward, W. A. (1997) Validation of dietary intakes of protein and energy against 24 hour urinary N and DLW energy expenditure in middle-aged women: retired men and post-obese subjects: comparisons with validation against presumed energy requirements. Eur. J. Clin. Nutr. 51: 405–413.

Bouten, C.V.C, Verboeket-van de Venne, W.P.H.G., Westerterp, K. R., Verduin, M. & Janssen J.D. (1996) Daily physical activity assessment: comparison between movement registration and doubly labeled water. J. Appl. Physiol. 81: 1019–1026.

Buhl, K. M., Gallagher, D., Hoy, K., Matthews, D. E. & Heymsfield, S. B. (1995) Unexplained disturbance in body weight regulation: diagnostic outcome assessed by doubly labeled water and body composition analyses in obese patients reporting low energy intakes. J. Am. Diet. Assoc. 95: 1393–1400.

Davies, P.S.W & Coward, W. A. (1994) Total energy expenditure and energy intake in the pre-school child: a comparison. Br. J. Nutr. 72: 13–20.

Edholm, O. G., Fletcher, J. G., Widdowson, E. M. & McCance, R. A. (1955) The energy expenditure and food intake of individual men. Br. J. Nutr. 9: 286–300.

Edwards, J. E., Lindeman, A, K., Mikesky, A. E. & Stager, J. M. (1993) Energy balance in highly trained female endurance runners. Med. Sci. Sports Exerc. 25: 1398–1404.

Fjeld, C. R., Brown, K. H. & Schoeller, D. A. (1988) Validation of the deuterium oxide method for measuring average daily milk intake in infants. Am. J. Clin. Nutr. 48: 671- 679.

Goldberg, G. R., Black, A. E., Jebb, S. A., Cole, T. J., Murgatroyd, P. R., Coward, W. A. & Prentice, A. M. (1991) Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur. J. Clin. Nutr. 45: 569–581.

Kempen, K.P.G, Saris, W.H.M & Westerterp, K. R. (1995) Energy balance during an 8-wk energy restricted diet with and without exercise in obese women. Am. J. Clin. Nutr. 62: 722–729.

Lichtman, S. W., Pisarska, K., Raynes Berman, E., Pestone, M., Dowling, H., Offenbacher, E., Weisel, H., Heshka, S., Matthews, D. E. & Heymsfield, S. B. (1992) Discrepancy between self-reported and actual caloric intake and exercise in obese subjects. N. Engl. J. Med .327: 1893–1898.

Livingstone, M.B.E, Prentice, A. M., Coward, W. A., Strain, J. J., Black, A. E., Davies, P.S.W, Stewart, C. M., McKenna, P. G. & Whitehead, R. G. (1992) Validation of estimates of energy intake by weighed dietary record and diet history in children and adolescents. Am. J. Clin. Nutr. 56: 29–35.

Livingstone, M.B.E, Prentice, A. M., Strain, J. J., Coward, W. A., Black, A. E., Barker, M. E., McKenna, P. G. & Whitehead, R. G. (1990) Accuracy of weighed dietary records in studies of diet and health. Br. Med. J. 300: 708–712.

Martin, L. J., Su, W., Jones, P. J., Lockwood, G. A., Tritchler, D. L. & Boyd, N. F. (1996) Comparison of energy intakes determined by food records and doubly labeled water in women participating in a dietary-intervention trial. Am. J. Clin. Nutr. 63: 483- 490.

Milne, A. C., McNeill, G. & Zakary, A. (1991) Weight change as an indicator of energy imbalance during 7 day weighed food intake studies. Ecol. Food Nutr. 281–289.

Pannemans, D.L.E & Westerterp, K. R. (1993) Estimation of energy intake to feed subjects at energy balance as verified with doubly labelled water: a study in the elderly. Eur. J .Clin. Nutr. 47: 490–496.

Prentice, A. M., Black, A. E., Coward, W. A., Davies, H. L., Goldberg, G. R., Murgatroyd, P. R., Ashford, J., Sawyer, M. & Whitehead, R. G. (1986) High levels of energy expenditure in obese women. Br. Med. J.292: 983–987.

Schoeller, D. A. (1990a) How accurate is self-reported dietary energy intake? Nutr. Rev. 48: 373–379.

Schoeller, D. A., Bandini, L. G. & Dietz, W. H. (1990b) Inaccuracies in self-reported intake identified by comparison with the doubly labelled water method. Can. J. Physiol. Pharmacol. 68: 941–949.

Schoffelen, P.F.M, Westerterp, K. R., Saris, W.H.M, Hoor, F. ten. (1997) A dual-respiration chamber system with automated calibration. J. Appl. Physiol. 83: 2064–2072.

Schulz, S., Westerterp, K. R. & Brück, K. (1989) Comparison of energy expenditure by the doubly labeled water technique with energy intake, heart rate, and activity recording in man. Am. J. Clin. Nutr. 49: 1146–1154.

Sjödin, A. M., Andersson, A. B., Högberg, J. M. & Westerterp, K. R. (1994) Energy balance in cross-country skiers: a study using doubly labeled water. Med. Sci. Sports Exerc. 6: 720–724.

Velthuis-te Wierik, E.J.M, Westerterp, K. R. & Berg, Van den H. (1995) Impact of a moderately energy-restricted diet on energy metabolism and body composition in non-obese men. Int. J. Obes. 19: 318–324.

Weir, J. B. (1949) New methods for calculating metabolic rate with special reference to predicting protein metabolism. J. Physiol. 109: 1–9.

Westerterp, K. R., Donkers, J.H.H.L.M., Fredrix, E.W.H.M. & Boekhoudt, P. (1995) Energy intake, physical activity and body weight: a simulation model. Br. J. Nutr. 73: 337–347.

Westerterp, K. R., Kayser, B., Brouns, F., Herry, J. P. & Saris, W.H.M. (1992) Energy expenditure climbing Mt. Everest. J. Appl. Physiol. 73: 1815–1819.

Westerterp, K. R., Robach, P., Wouters, L. & Richalet, J. P. (1996) Water balance and acute mountain sickness before and after arrival at high altitude of 4,350 m. J. Appl. Physiol. 80:1968–1972.

Westerterp, K. R., Verboeket-Van de Venne, W.P.H.G., Meijer, G.A.L & Hoor ten, F. (1991) Self-reported intake as a measure for energy intake. A validation against doubly labelled water. Obes. Eur. 91: 17–22.

Weststrate, J. A., Weys, P.J.M, Poortvliet, E. J., Deurenberg, P., Hautvast, J.G.A.J. (1989) Diurnal variation in postabsorptive resting metabolic rate and diet-induced thermogenesis. Am. J. Clin. Nutr. 50: 908–914.